Astrophysics Research And Analysis

Stacked Wafer Gradient Index Silicon Optics with Integral Antireflection Layers

Completed Technology Project (2015 - 2017)

Project Introduction

A wide range of applications in submillimeter and millimeter wavelength astronomy, on the ground and in space, would benefit from silicon optics with broadband antireflection treatment. Silicon's high refractive index and low loss make it an ideal optical material at these wavelengths. It is even possible to use silicon for ambient temperature vacuum windows. Antireflection treatment of silicon optics is essential, however, and has proven a major challenge for the 15 cm to 100 cm diameter optics required for current and future applications. Moreover, multilayer antireflection treatments are necessary for wide spectral bandwidths, with wider bandwidths requiring more layers. It is difficult to find low loss dielectrics with the correct refractive index and other properties to match silicon well, especially if more than one layer is required. Textured surfaces are an attractive alternative to dielectric antireflection coatings. For millimeter wavelengths, a two layer antireflection texture with modest bandwidth has been cut successfully into silicon lens surfaces with a dicing saw. Both the innermost layers of multilayer structures and antireflection structures for submillimeter wavelengths require, however, finer features than a saw is capable of producing. Deep reactive ion etching works well on flat surfaces but there are limits to the depth and aspect ratio of the features it can create. Furthermore etching has not been adapted to large, curved optics. We propose a different approach to this problem: construct a silicon optic by stacking flat patterned wafers.The starting point is a multilayer optical design incorporating both an axial gradient in the refractive index for antireflection and a radial index gradient for focussing. For each optical layer, an aperiodic hole pattern is used to achieve the required effective index of refraction. Using a novel multilayer etching procedure, several layers of the optical structure are fabricated on a flat wafer. Several individually patterned wafers are stacked and bonded together to produce the completed optic. Although the component technologies are mature, they have not been previously combined this way. Initial calculations indicate this technique will work. As a demonstration, therefore, we propose to undertake detailed designs and simulations and then to prototype optical elements up to 15 cm in diameter. Our objective is to develop a technique for fabricating novel silicon optics with integral achromatic antireflection (AR) layers by bonding stacks of etched silicon wafers.

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Organizational Responsibility

Responsible Mission Directorate:

Science Mission Directorate (SMD)

Responsible Program:

Astrophysics Research and Analysis

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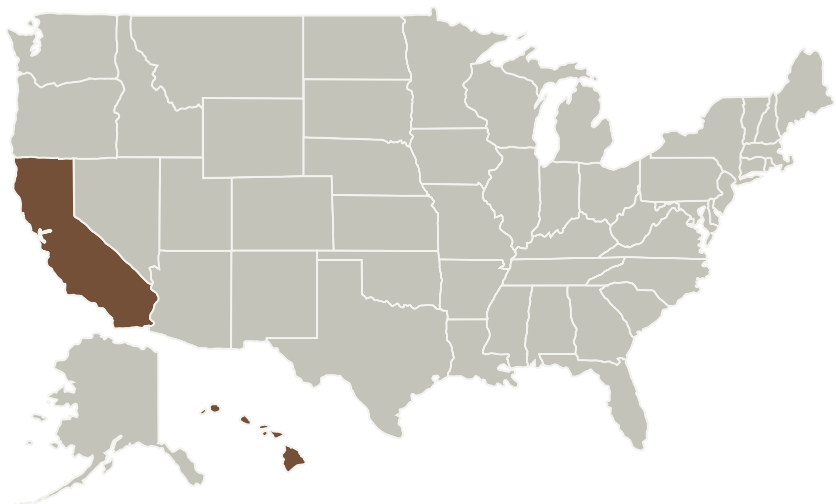
Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
California Institute of Technology(CalTech)	Supporting Organization	Academia	Pasadena, California

Primary U.S. Work Locations	
California	Hawaii

Project Management

Program Director:
Michael A Garcia

Program Manager:
Dominic J Benford

Principal Investigator:
Simon J Radford

Co-Investigator:
Goutam Chattopadhyay

Technology Areas

Primary:

- TX08 Sensors and Instruments
  - └ TX08.2 Observatories
    - └ TX08.2.1 Mirror Systems

Target Destination

Outside the Solar System